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DEAD POLLENIA RUDIS (FABR.) AS HOSTS OF DERMESTIDS.

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Early this spring (1928) several complaints were received by the Department of Biology of the University of Toronto, of infestations of dwelling houses by Dermestids. The most pronounced case was in a new house in the newer section of North Toronto where beetles had been appearing in such numbers that their presence and continued reoccurrence was driving the tenants to hysterics and to the point of moving out of the house. Specimens brought in proved to be *Anthrenus scrophulariae* Linn. larvae and adults.

The tenants stated that they had searched every nook and cranny of the house for possible breeding places and had cleaned out every closet and cupboard, but the beetles still persisted. Dr. Norma Ford suggested that they might be breeding in dead bodies of the Cluster fly *Pollenia rudis* (Fabr.) which was reported to occur in the unused attic.

Upon inspecting the house, I found it scrupulously clean from ceiling to basement but beetles of two species *Anthrenus museorum* L. and *A. scrophulariae* L. in the proportion of two to one respectively, were present in some numbers especially around the windows on the south side of the house and crawling up from cracks behind mould-boards behind radiators. The only visible damage was a series of holes eaten in the topmost folds of a heavy silk plush curtain from which the owner had removed the larvae she had brought in for identification. The attic was partly unfinished and was reached only by a trap door in the hall ceiling. The floor boards of the attic were literally carpeted with dead bodies of *Pollenia rudis* (Fabr.) while live flies crawled in dense masses along the window sills. I crushed and examined a square yard of dead flies and found a heavy infestation of *A. museorum* L. occurring as larvae in all stages of development, pupae, and adults about to emerge, but not a trace of *A. scrophulariae* L. There were no adult beetles crawling around the windows amongst the flies so that upon emergence, they must all have crawled down to the warmer parts of the house.

The breeding place of *A. scrophulariae*, L. was not discovered.

Pollenia rudis (Fabr.) has been unusually abundant in Toronto this spring and many enquiries about it have been sent in to the Department of Biology. From the findings in this instance, it might in future be advisable to spray any masses of this fly that occur in attics and to sweep up and burn their bodies lest they furnish breeding places for harmful Dermestids.

THE EVOLUTION OF THE HEAD REGION IN LOWER ARTHROPODS AND ITS BEARING UPON THE ORIGIN AND RELATIONSHIPS OF THE ARTHROPODAN GROUPS.

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As is indicated by the numbering of the figures in the accompanying plates, the following discussion of the head capsule of lower Arthropods is a continuation of the discussion of the head capsule of higher Arthropods given in a previous paper (Canadian Entomologist, LX, 1928, p. 129). The figures were numbered consecutively throughout all of the plates which were originally intended for inclusion in a single paper, and the original numbering has been retained in the accompanying plates (despite the fact that limitation of space necessitated dividing the original discussion into two parts) because reference was made to certain of the accompanying figures in the previous paper, and it would create confusion to later change the numbers which had been referred to in a previous paper. On this account, the accompanying plates begin with "Fig. 55," instead of "Fig. 1."

The Cumacean *Diastylis* and the Phyllocaridan *Nebalia*, here figured, are Malacostraca, and had space permitted it, these forms should have been discussed in the previous paper dealing with the Malacostraca and their relatives among the higher Arthropods. *Nebalia* and *Diastylis*, however, may quite profitably be discussed in the present paper dealing with the lower Arthropoda, since *Nebalia* in particular is supposed to lead back to the lower Crustacea such as the Entomostraca here considered.

As far as *Diastylis* is concerned, its head capsule (Fig. 62) is too greatly modified to offer any very serviceable clues as to its origin; and, despite the fact that *Diastylis* supposedly stands at the base of the Tanaidacean and Isopodan lines of descent, the lower Tanaidacean and Isopodan types of head capsule shown in Figs. 50, 34 and 29 (of the previous paper) are infinitely more primitive, in their general features, than *Diastylis* is. With the Anaspidacean type shown in Fig. 27, these Tanaidacean and Isopodan types apparently lead back to some form more like *Mysis* (Fig. 52); and in all probability the Tanaidacea (with the Isopoda) Anaspidacea and Mysidacea sprang from a common stock from which the Mysidacea have departed but little.

A study of the head region would indicate that the Euphausiacea (Fig. 51) are somewhat closer to the Decapoda (Figs. 53 and 54) than they are to the Mysidacea (Fig. 52); and the Euphausiacea stand at the base of the Decapod stock. *Mysis* (Fig. 52), however, is "built" on the same general plan as that exhibited by *Euphausia* (Fig. 51) and the typical Decapoda (Figs. 53 and 54), and *Mysis* is very much more primitive than these forms, so that it is a very reasonable conclusion that the lines of descent of the Euphausiacea and Decapoda lead back to *Mysis*-like ancestors. In other words, *Mysis* has retained many of the ancestral features from a common ancestry.

The Stomatopoda such as *Squilla* (Fig. 49) have a "jointed" rostrum *r*, anteriorly situated eyes *e*, and the bases of the antennae are attached in a direct line (at the same level) behind the attachment of the eye-stalks, thus resembling

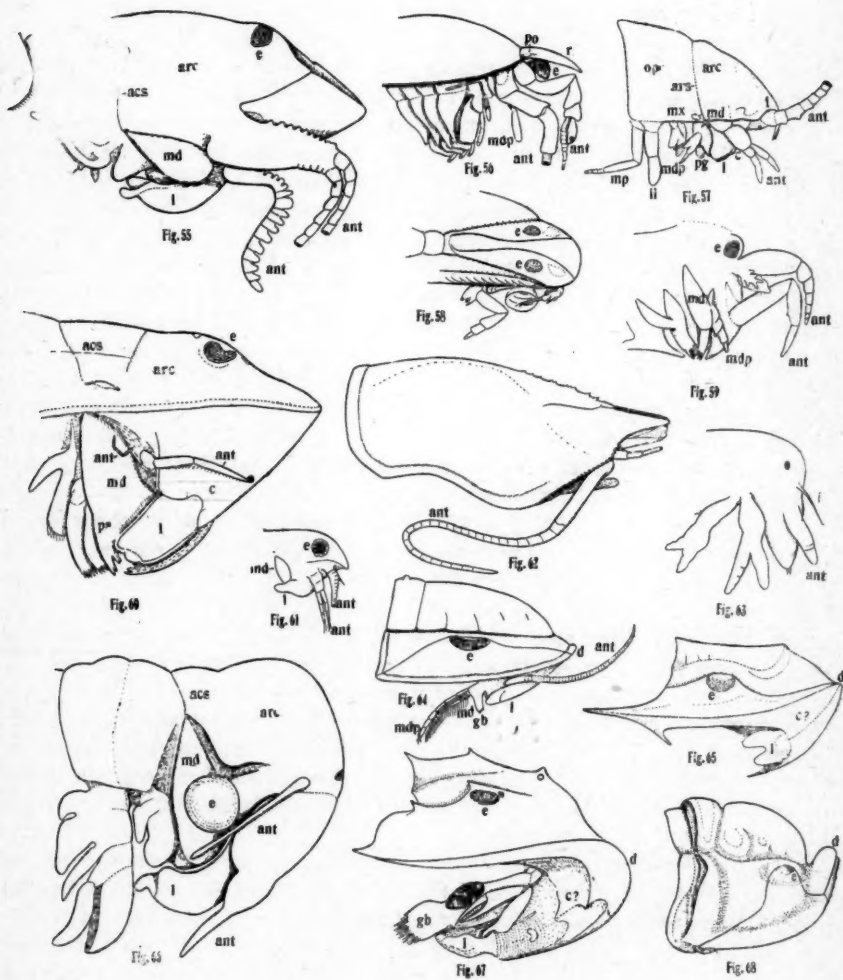
Nebalia (Fig. 56) in these respects; and, in fact, the Stomatopoda appear to approach the Nebaliacea as closely as any of the Malacostracan forms do. The general features of the Stomatopoda, however, would not indicate a very close relationship to the Nebaliacea, but would indicate a far closer relationship to the Decapoda, Euphausiacea, and Mysidacea.

A study of the head capsule would thus indicate that the Stomatopoda, Decapoda and Euphausiacea lead back to some forms like the ancestral Mysidacea; and the Tanaidacea, Isopoda and Anaspidacea apparently also lead back to forebears like the ancestral Mysidacea (and as will be discussed later, this has some bearing upon the question of the origin of the Insecta and "Myriopoda"). The primitive representatives of all of these groups (Figs. 49, 50, 52, 27, etc.) indicate that the head-capsule of their distant ancestors exhibited the following characters which are well exemplified in the Copepod head shown in Fig. 57, namely, a well-developed, downward-projecting clypeus and labrum *c* and *l* of Fig. 57, a well-developed archicephalic suture *acs*, and a distinct maxilliped *mp** more closely associated with the opisthocephalic head region *opc* than with the following region of the body. In these important features, *Nebalia* (Fig. 56)—which is supposed to stand at the base of the Malacostracan stem—fails to qualify as an ancestral type, while the Copepoda easily qualify as ancestral types furnishing very suitable starting points for tracing the modificational tendencies which manifest themselves in the lines of descent of the higher forms mentioned above. Thus, for example, *Nebalia* (Fig. 56) instead of having a downward-projecting, well developed clypeal and labral region, has these regions greatly flattened and so reduced that they are seen only with difficulty.

The head of *Nebalia* (Fig. 56) is not divided by an archicephalic suture into an anterior and posterior head region, and the maxilliped is not more closely associated with the head than with the rest of the body. From these and many other features, I am inclined to regard *Nebalia* (Fig. 56) as a very isolated form arising from a primitive stock which was derived from the common ancestors of the Branchiopoda (Figs. 55, 60 and 66) and Copepoda (Fig. 57), although this primitive stock was more closely allied to the ancestral Malacostraca than to any other forms. The ancestral Malacostraca giving rise to the Mysidacea (Fig. 52) Anaspidacea (Fig. 27) etc., apparently lead back to the common Branchiopodan-Copepodan stem; but the Copepoda (Fig. 57) have retained more of the ancestral features characteristic of the precursors of the Malacostraca than any other forms of which I have any knowledge.

Since the Copepoda are such primitive forms and present so many features characteristic of the forerunners of the higher Crustacea in which the head is divided by an archicephalic suture (*arc* of Figs. 27, 50, 52, etc.) into an "archicephalon" *arc*, and opisthocephalon *opc*, it is of some interest to note that the mandible *md* of the Copepod shown in Fig. 57 is more closely associated with the posterior or opisthocephalic head region *opc* than with the anterior or archicephalic head region *arc*. Embryology likewise indicates that the mandibles belong

*—It should be noted that the appendage which I have homologized with the first maxilliped, in the Crustacean shown in Fig. 57 (i.e. the appendage labelled *mp*), is interpreted as a branch of the maxilla *li* by some students of the group Copepoda. If their interpretation is correct, the head of a primitive Copepod would contain only five pairs of appendages, like the head of an embryo Insect.



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with the first and second maxillae in the "ganthocephalon," or posterior head region, rather than with the second and first antennal segments, etc., in the anterior head region. If this be true, the mandibular segment would lie behind the archicephalic suture *acs* of *Anaspides* (Fig. 27) and *Machilis* (Fig. 8), despite the fact that the mandible itself apparently lies in front of this suture in the forms mentioned. Since the archicephalic suture is apparently retained in some insects, it is of considerable interest to determine whether the mandibular segment lies in front of or behind the archicephalic suture, and judging from the condition exhibited by the primitive Crustacean shown in Fig. 57, it would appear that the mandibular segment lies behind the archicephalic suture.

The head region of such Copepods as *Argulus* (Fig. 58), which belongs to the rather primitive Copepodan group Branchiura, bears a marked resemblance to the head region of *Apus* and *Lepidurus* (Fig. 60) among the Branchiopoda, and this may be interpreted as indicating that the ancestral Copepoda merge with the ancestral Branchiopoda very quickly as we trace their lines of descent back to their common ancestors in the common Copepodan-Branchiopodan stem. These ancestral forms were evidently more Crustacean than Trilobitan, but they were approached by certain Trilobitan types remarkably closely. The common ancestral forms in the ancestral Copepodan-Branchiopodan stem gave rise not only to the Copepoda and Branchiopoda, but also to the ancestral Ostracoda and Cirrepedia, etc., and in all probability the ancestral Malacostraca (including the ancestors of Nebalia) were eventually derived from forms in this common stem resembling Copepods in many respects.

While the Copepoda are interesting in that they resemble the forms giving rise to the ancestral Malacostraca (with the ancestral Mysidacea preserving many of the ancestral features present in the early Malacostraca), the Branchiopoda are likewise of great interest in tracing the evolution of other Crustacea. Among the Branchiopoda, the head of the Conchostraca exemplified by *Estheria* (Fig. 55) is intermediate between the head of the Anostraca as exemplified by *Branchippus* (Fig. 66) and the head of the Notostraca as exemplified by *Lepidurus* (Fig. 60). Thus in *Estheria* (Fig. 55) the general outline of the labrum *l* is more like that of *Branchippus* (Fig. 66), the general outlines of the mandibles *md* are more alike in *Estheria* and *Branchippus*, and the archicephalic suture *acs* is complete in *Estheria* (Fig. 55) and *Branchippus* (Fig. 66), while the appendages following the mandibles tend to become more reduced in *Estheria* and *Branchippus* (or more markedly in *Artemia* shown in Fig. 77) than in *Lepidurus*. The general outline of the head of *Estheria* (Fig. 55) however, is more like that of *Lepidurus* (Fig. 60), so that a study of the various features of the head would indicate that the Conchostraca such as *Estheria* are intermediate between the Anostraca such as *Branchippus* and the Notostraca such as *Lepidurus* (a more familiar example of the Notostraca is *Apus*). *Estheria* (Fig. 55) is not only intermediate between *Branchippus* and *Lepidurus* in its head characters, but its type of head clearly leads over to the Cladoceran type of head capsule, as may be seen by comparing Fig. 55 with Fig. 61, and the evidence of the head structures clearly supports that from the study of other parts of the body indicating that the Cladocera, Conchostraca, Notostraca and Anostraca form

a compact group, the Branchiopoda, whose members are connected by such Conchostraca as *Estheria*.

I have not been able to obtain for study suitable material of the primitive Ostracoda and Cirrepedian larvae, and it is very difficult to draw any conclusions concerning the interrelations of the structural details of the head parts from the drawings of persons who are not greatly interested in comparative anatomy. From the re-drawn figure of the head of *Cypris* shown in Fig. 59, however, one may conclude that the primitive Ostracodan head was doubtless derived from precursors in the common ancestral stem which gave rise both to the Copepoda, with mandibular palpi, etc., and to the Branchiopoda with well developed eyes, etc. Some features of the Ostracoda suggest Copepodan affinities, and others suggest Conchostracan affinities, so that we may more logically assume that the ancestral forms giving rise to the Copepoda and Branchiopoda (including the Conchostraca) were the precursors of the Ostracoda also. The head of the larval Cirrepedian shown in Fig. 63 might easily be derived from an Ostracodan type such as that shown in Fig. 59, and it is quite possible that the Ostracoda were like the ancestors of the Cirreperia; although it is also possible that the ancestors of the Ostracoda in the common Copepodan-Branchiopodan stem gave rise to the Cirreperia, instead of the Ostracoda standing more directly in the line of descent of the Cirreperia. The Ostracoda and Cirreperia, however, are of no especial interest for tracing the evolution of other Crustacea and related Arthropods, and need not be further considered at this time.

In tracing the common stem of the Copepoda and Branchiopoda back to their more primitive Arthropodan precursors, the Trilobita must be next considered, since these Arthropods are more primitive than any Crustacea now living, and show many points of contact with the true Crustacea and with the Arachnoids. Walcott considers that *Marella* (Fig. 79) is a Trilobite with close affinities with the Anostracan Branchiopoda such as *Branchippus* and *Artemia* (Figs. 66 and 77); and recent investigators would derive the Branchiopoda from Trilobites through such forms as *Marella*. *Marella*, however, is evidently specialized along its own peculiar paths of development (such as the development of elongated processes of the head etc.) In fact, *Marella* may be a Branchiopod itself, and I cannot see that the head of *Marella* is sufficiently primitive to serve as the prototype for Branchiopods in general (compare Figs. 66 and 79).

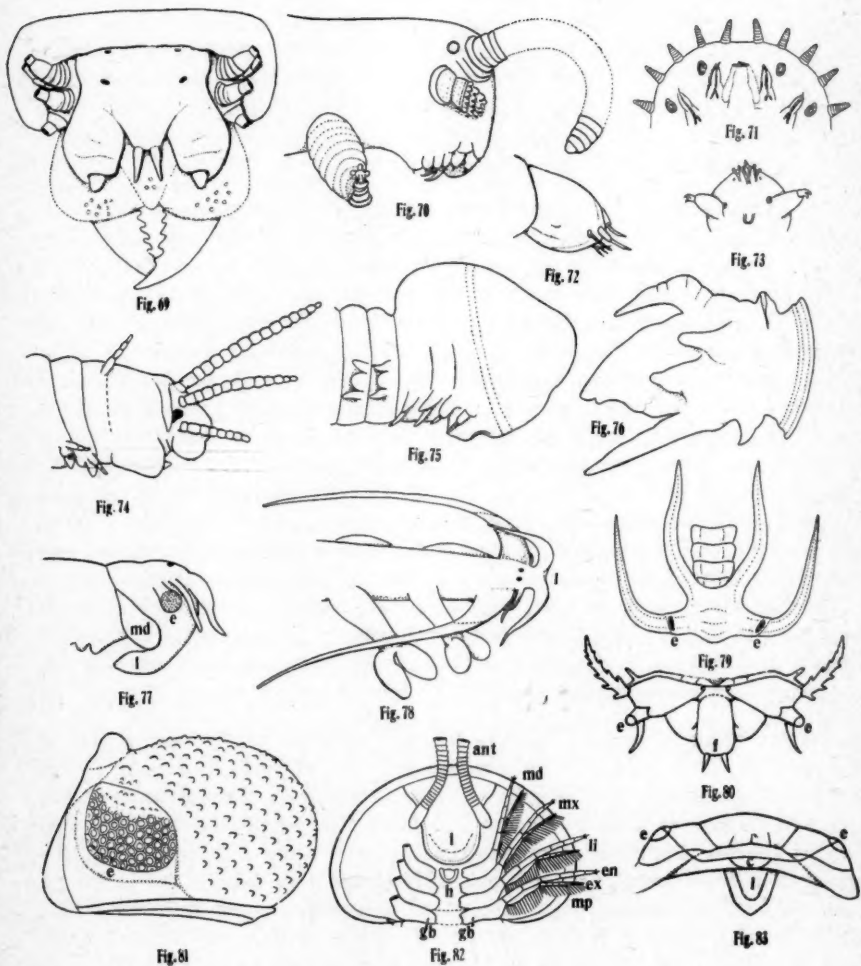
I am much more inclined to derive the common ancestral Copepodan-Branchiopodan group from Crustacean forebears which arose from the *ancestral* Trilobites, or "Prototrlobites," rather than from any known type of Trilobite, since the main Trilobitan evolutionary trends in the head region, for example, tend to follow the Arachnoid, rather than the Crustacean paths of development. Thus none of the known types of Trilobites tend to develop compressed heads with downwardly projecting clypeal and labral structures, and with head capsules divided by an archicephalic suture into an anterior and posterior head region, or with mandibles of the Crustacean type etc. etc., while practically all Trilobitan types of head capsule tend to develop along the *Arachnoid* line of evolution in having flattened heads (with a doublure) with ambulatory mouthpart-limbs provided with gnathobases for chewing food, etc., as in *Limulus* for example, as will be discussed later. I am therefore more inclined to derive the "ProtoCrustacea"

(common Copepodan-Branchiopodan ancestral forms) from "Prototrilobita" exhibiting Crustacean tendencies, than from any known Trilobitan forms, even such forms as *Marella* (if it be a true Trilobite).

Lichas (Fig. 80) is a Trilobite exhibiting adumbrations of the stalked eyes of Crustacea, in that the eyes of *Lichas* are borne at the ends of processes which are demarked, by basal depressions, from the head capsule, in a fashion clearly adumbrating the stalked eyes of Crustacea. This, however, should not be taken to indicate that *Lichas* is in any sense ancestral to the Crustacea, since the primitive Trilobita and Crustacea probably both had sessile eyes (compare Figs. 62, 55, etc.), and according to the adumbration theory, foreshadowings of modifications later cropping out in some members of a derived group may occur in some members of an ancestral group, without all of the primitive members of either group exhibiting such tendencies.

The stalked eyes of some Crustacea exhibit some interesting modifications to which I would call attention at this point. The eyes of the Decapods shown in Figs. 53 and 20 are borne on remarkably flattened plates which are doubtless the modified eye-stalks, although I at first thought that the projecting processes labelled *po* in Fig. 56 of *Nebalia* might fuse with the eye-stalks to form the enlarged plates of the Decapoda in question. The eye-stalks are considered by some to represent modified appendages homodynamous with the antennae and mouthparts etc., but they are more probably simply modified outgrowths of the head capsule carrying the eyes with them, and the primitive condition appears to be the sessile-eyed one, although it is possible that after stalked eyes had become developed in some Crustacea, the sessile-eyed condition might be again assumed by the reduction and ultimate disappearance of the eye-stalks. While the eye-stalks do not represent modified limbs, there is apparently an ocular segment in the head of Arthropodan embryos; and Dr. Walcott formerly showed me a Trilobite having what he interpreted as a well marked ocular segment in the head capsule, and it would be extremely interesting to make a study of the head capsule of this form, to determine the boundaries of the segments entering into the composition of the head capsule of Trilobites in general.

According to recent observers the interpretation of the appendages of the head of Trilobites given by Beecher and his followers is incorrect; and instead of interpreting the five pairs of head appendages of *Triarthrus* (Fig. 82) as the first antennae, second antennae, mandibles, first maxillae and second maxillae as Beecher did, recent observers consider that a pair of antennae has disappeared in Trilobites, and the first pair of biramous limbs labelled *md* in Fig 82, represents the mandibular limbs, instead of being homologous with the second antennae, of Crustacea. I have followed the more recent views in this paper, because the hypopharynx (sometimes accompanied by a pair of paragnaths) is never situated between the bases of the second antennae, but is frequently situated between the bases of the mandibles (the accompanying paragnaths being detached lobes of the mandibular segment), and since the median structure labelled "h" in Fig. 82 evidently represents the hypopharynx (or possibly the united parag-



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naths*), the appendages on each side of it must be the mandibular limbs instead of the second antennae. Since the appendages *md* evidently represent the mandibles in Fig. 82, the appendages following the mandibles represent the first maxillae, second maxillae and first maxillipeds, as indicated by the labelling; and the Trilobitan head thus corresponds very closely to the Crustacean head in having the first maxillipeds more closely associated with the head capsule than with the body region immediately behind the head, although the Branchiopodan Crustacea do not exhibit this tendency for the maxillipeds to become associated with the head region, and are more like insects in this respect (the first maxilliped associated with the head capsule in higher Crustacea, is homologous with the prothoracic leg of insects, which is not associated with the head, although its homologue the poison-claw of Chilopods is associated with the head, like the first maxilliped of higher Crustacea). This correction of the interpretation of the appendages of the Trilobitan head removes the strongest argument advanced for deriving Insects from Trilobites, since the head capsule in general in Trilobites is nothing like the Insectan type, and only the supposed agreement in the number of segments entering into the composition of the head capsule of Insects and Trilobites served to give any degree of plausibility to the argument that Insects might be derived from Trilobitan forebears.

There is a feature of locomotion which is not sufficiently stressed in comparing the different types of Arthropods together, and I would use this feature to introduce the discussion of the types of head appendages exhibited by Trilobites and Arachnoids at this point. Crustacea, "Myriopods" and Insecta are essentially "Cormogradi," walking upon the limbs of the trunk region instead of the head appendages, while such forms as the Aglaspina, Xiphosura and Arachnida in general are "Cephalogradi," walking upon the limbs homologous with the head appendages. Trilobites, on the other hand walk upon the limbs of both head and trunk regions, and are therefore "Amphigradi," in a sense intermediate between the two main groups but in so far as they employ the head limbs for walking, they are "Cephalogradi" also. Since Trilobites use the head appendages for locomotion, they employ the gnathobases (*gb* of Fig. 64 and Fig. 82) of the head limbs for chewing their food, just as Merostomes such as *Limulus* now use the gnathobases (*gb* of Fig. 67) of their head appendages for chewing worms upon which they feed. The head limbs of Trilobites are thus essentially like the head limbs of Merostomes and other Arachnoids in using the gnathobase of the limb for chewing, while employing the rest of the limb for locomotion; and the Trilobitan head appendage is thus fundamentally Arachnoid (or "Merostomatoid") despite the fact that it is biramous (i. e. has an exopodite as well as an endopodite†, and is therefore considered more Crustacean than Merostomatoid by some). The fact that Crustacea, Myriopods and Insects have "gnathiform" mandibular appendages of the true mandibular type, while Trilobites have only ambulatory limbs provided with gnathobases, after the fashion of Merostomes and other primitive

*—Dr. Raymond tells me that the structure in question is sometimes bilobed in Trilobites, thus suggesting that it may be formed by the united paragnaths; but in any case it occupies the position of the hypopharynx, whether the latter is accompanied by paragnaths or not.

†—It is not improbable that even Merostomes exhibit traces of biramous head appendages if the so-called exopodite on the hind leg of *Limulus*, for example, is really an exopodite, and therefore making the hind limb a biramous one.

Arachnoids, clearly indicates that the Trilobitan trends are more in line with those exhibited in the evolution of Arachnoids, than they are in agreement with the typical trends of Crustacean, "Myriopodan" and Insectan development, and the same is true of all of the mouthparts and features of the head-capsule in general.

Although some Crustacea such as *Lepidurus* (Fig. 60) have for some reason retained the flattened head and Trilobitan form of labrum *l*, etc., it is quite evident to anyone making a comparative study of the Crustacea that the main trends of Crustacean evolution exhibited by the Crustacea shown in Fig. 57, 52, 50, 27, etc., lead away from the Trilobitan type and lead toward the type having a compressed head, with downward projecting labrum and clypeal region, and with the head divided by an archicephalic suture *ars* into an anterior and posterior region, etc., which tendencies are further developed in the Insecta etc., but are not developed in the Arachnoids. Thus, the typical Trilobitan head capsule shown in Fig. 65 lacks the archicephalic suture, and shows no trace of a division into an anterior and posterior region (as for example is shown in the head of the typical Crustacean shown in Fig. 57), but is flattened and in all essential features is like the head of the primitive Arachnoid shown in Fig. 67, just as its head-limbs are like those of the primitive Arachnoids rather than like those of typical Crustacea, and this is what I referred to above in stating that the main Trilobitan trends lead away from the evolutionary developmental tendencies typical of Crustacea, Insects, etc., and lead toward those typically exhibited by primitive Arachnoids.

There are no detailed reconstructions of the fossil orders Aglaspina and Limulava described by Walcott as intermediate in their general features between Trilobites and the rest of the Merostomata, but if we start with the typical Trilobitan head capsule shown in Fig. 86, and pass through the primitive Mero-stome type shown in Fig. 85 to the Scorpion-like type shown in Fig. 84 (a Euryp-terid very like the ancestors of the Scorpions), or if we compare the Trilobitan type of head shown in Fig. 89 with the primitive Arachnoid type shown in Fig. 90, it should be immediately apparent to any unbiased person that the fundamental tendencies in the formation of the head capsule of the Trilobites and primitive Arachnoids are essentially the same, and the Trilobitan type differs from the typical Crustacean trends in proportion to its closer approach to the primitive Arachnoid type. The insertion of antenna *ant* in *Bunodes* by Patton (from whose figures Fig. 85 was re-drawn) may have been an error, but the Aglaspina apparently had antennae, and their head capsules, no less than that of *Bunodes* (Fig. 85), lead from such a Trilobitan type as the one shown in Fig. 86, to the Euryp-terid type shown in Fig. 84, and thence to the various Scorpionid types such as the one shown in Fig. 87, while the Trilobitan type shown in Fig. 89, with its angulate posterior lateral projections is like the head of *Limulus* shown in Fig. 90, and the general character of the Trilobitan head shown in Fig. 65 is like that of *Limulus* shown in Fig. 67. Both Trilobitan and primitive Arachnoid types of head capsule are flattened, without downward projecting clypeal and labral regions, and are unlike the Crustacean types with their compressed head capsules divided by an archicephalic suture into an anterior and posterior region, so that we are amply justified in stating that the main Trilobitan trends of head capsule

development are away from those of typical Crustacea and Insecta, and are toward the developmental tendencies exhibited in the head capsules of primitive Arachnoids.

The Pedipalpi of the whip-scorpion and Tarantula types shown in Figs. 88 and 91 together with the spider types (Fig. 92) could readily be derived from some Scorpionid type (e. g. Fig. 87); and possibly the Pseudoscorpionida, which are distantly related to the Podogona and to the Phalangiida (standing at the base of the ancestral stem of the mites and ticks) were derived from Scorpion-like precursors; but the Palpigradi (*Koenenia*) and their near relatives the Solpugida which are also related to these forms (particularly to the Pseudoscorpionida) present some difficulties in deriving their type of head capsule (which does not contain as many segments as the Scorpionid type) from Scorpion-like forebears. The head of the Solpugid shown in Fig. 93 is very much like that of *Koenenia* in that the segments bearing the hinder limbs do not unite with the head capsule but remain more or less free; but I do not think that the number of segments entering into the head capsule is a feature of fundamental importance for separating forms which are otherwise exceedingly similar, or for denying a common ancestry to forms which differ in the number of segments composing the head capsule, provided that these forms exhibit other features clearly indicating that they sprang from a common ancestry, as is the case with the Palpigradi, Solpugida and other Arachnoids such as the Podogona, Phalangiida, Pseudoscorpionida etc.; and I do not know of anyone who would deny the close interrelationships and common ancestry of all these Arachnoids despite the differences in the segmental composition of their head capsules, any more than they would deny the close relationships and common ancestry of such Malacostraca as the Isopods and Mysidacea, which also differ in the number of segments exhibiting a tendency toward cephalization; yet some investigators are unwilling to grant a common ancestry to Insects and Crustacea because apparently only six segments become cephalized to form the Insectan type of head, while one or more additional segments may become added to the heads of higher Crustacea. It should be quite apparent that the feature of adding segments to the head region is one which in no wise affects the common ancestry and close relationships of Arthropods within the class Crustacea or the class Arachnoidea, and similarly, the adding of segments to the head region should be given no great weight as an argument against granting a common ancestry to Crustacean and Insectan Arthropods, if many features indicate that these forms sprang from a common ancestry. I have stressed this matter at this point because the Solpugida and Palpigradi offer excellent examples of forms differing from the rest of their allies in the composition of their head capsules without this fact suggesting to anyone that the Solpugida and Palpigradi had any other than a common ancestry with the forms obviously closely related to them; and when entomologists realize that closely related Arthropods can differ in the composition of their head capsules without causing anyone to propose that such Arthropods could not be descended from a common ancestry, it is to be hoped that the unwarranted opposition to deriving Insects and Crustacea from a common Crustaceoid ancestry because of slight differences in the composition of the head capsules of the two groups, will cease, and the fundamental resemblances



Fig. 84

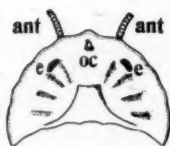


Fig. 85



Fig. 86

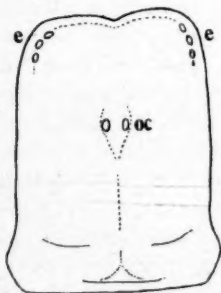


Fig. 87

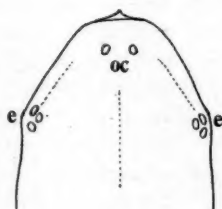


Fig. 88



Fig. 89

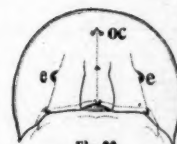


Fig. 90

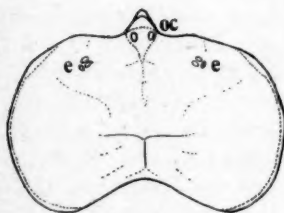


Fig. 91



Fig. 92

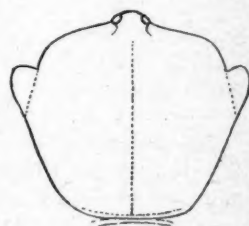


Fig. 93

between Insects and Crustacea will be accorded the attention their importance deserves!

In the foregoing discussion, I have emphasized the fact that most of the evolutionary tendencies exhibited in the head region of Trilobites lead away from the characteristic Crustacean types and toward the primitive Arachnoid types. This, however, should not be taken to mean that the primitive Trilobites were not like the ancestors of primitive Crustacea, since such undoubtedly was the case, as is attested by innumerable resemblances between the Trilobita and Crustacea. On the other hand, when one takes into consideration the even more numerous points of resemblance between the Trilobita and Merostomata (or forms like the Aglaspina and Limulava) the only logical conclusion to be drawn is that both Crustacea and Arachnoidea arose from Trilobite-like forebears in the Prototrlobitan stem, which probably comprised the first Arthropodan types to evolve, or were the direct descendents of the first Arthropods.

The nauplius stage characteristic of Crustacea in general, has not been considered in attempting to determine the nature of the ancestors of the group, because a free swimming nauplius larva is obviously specialized in adaptation to its own conditions of existence, and no more represents the ancestral condition for Crustacea in general than a larval Dipteron of the maggot type, without head, legs, etc., represents the ancestral condition of the Diptera. A nauplius larva has an obviously reduced body, with only three pairs of head appendages, and it has a condensed nervous system and other internal features of a wholly different character from what we know must have occurred in the ancestral Crustacea, and it is absurd to attempt to derive the primitive Crustacea, which were apparently very like the primitive Arthropods in general, from such a source.

Fundamentally, the bodies of Arthropods and Annelid worms consist of a series of segments or metameres (some of which bear appendages) traversed by a dorsal blood vessel, a central alimentary canal, and a ventral nerve chain (connected with a dorsal brain by circumoesophageal commisures) and such fundamental resemblances can be accounted for only on the grounds of a common heritage; and the Annelids being the more primitive, have departed the least from the common ancestry from which both Annelids and Arthropods sprang. Furthermore, the Annelids exhibit many adumbrations of features later cropping out in the derived group Arthropoda, in that some Annelids such as the one shown in Fig. 74 have jointed appendages, while others such as the one shown in Fig. 78 have a prostomium labelled *l*, which is evidently the precursor of the labrum of primitive Arthropods,* and some larval Annelids, such as the one shown in Fig. 75, have a number of segments (probably six) grouped into a head region demarked from the trunk, and suggestive of the precursor of the head region of primitive Arthropods. These, and many other features clearly indicate that the Annelids represent as nearly as any known forms, the ancestors of the Arthropoda, which were apparently derived either directly from Annelids or from a common ancestry with the Annelida.

The head of an Onychophoran such as the one shown in Fig. 70, is some-

*—It is very probable that not only the labrum, but also the clypeus and frontal regions (and possibly the areas around the eyes) are derived from the prostomium.

what suggestive of the precursor of the primitive Arthropodan type, but the Onychophora are probably abortive attempts in the direction of the Arthropoda on the part of Annelid-like forms, which later succeeded in producing true Arthropods.

The Tardigrade head shown in Fig. 72 is not very suggestive as a type ancestral to the Arthropodan type of head capsule; and since Tardigrades resembled the Onychophora in many respects, it is not wholly improbable that further research will indicate that the Tardigrada should be grouped with the Onychophora.

The Myzostomidan head shown in Fig. 71, is suggestive of both Annelids and Onychophora (including the Tardigrades) but offers no clues as to the origin of the Arthropodan head, and whatever these forms have in common may be the result of inheritance from Annelid forebears.

The head of a Linguatulid such as the one shown in Fig. 73, is extremely specialized, and if it approaches the type of head exhibited by some mites, it can hardly be considered as standing near the ancestral type of Arthropods in general, since the mites occupy a position at the extreme tip of the Arachnoid line of development, far removed from the base of the Arthropodan stem; and the head of a typical Linguatulid offers no primitive features for determining the character of the head region of the ancestral Arthropoda.

I have included Fig. 76 of the Rotifer *Pedalion*, because it has been seriously urged that the Rotifera are like the ancestors of the Arthropoda; but the head region of these Rotifers offers no support for such a view, and it is difficult to understand how anyone could maintain that Arthropods were derived from such a source.

I have not included figures of the head region of leeches and similar forms which some consider as near the ancestors of Arthropods, since the heads of these creatures are even less like the typical Arthropodan head than are the forms I have figured to show that they cannot be offered as suitable precursors for deriving the Arthropodan types; and space does not permit the discussion of every untenable suggestion concerning the nature of the ancestors of Arthropods, based for the most part upon supposed resemblances between Arthropods and other forms which, upon examination, are found to bear only the most superficial vague resemblance to arthropods in the general contour of the body, or some such inconsequential feature.

The relationships sketched above may be briefly summarized as follows. The Onychophora and Annelida are closely related forms which exhibit many adumbrations of features later cropping out in the Arthropodan descendants of Annelid-like precursors. The first Arthropods to be derived from these Annelid-like precursors were probably "Prototrilobites," from which were evolved in one direction the Trilobites leading to the Aglaspina and Limulava, which in turn gave rise to the Eurypterida and Xiphosura; and from forms like these arose the Scorpion-like forms leading to the other Arachnoids. Evolving in another direction from the "Prototrilobites" were the Crustacea-like Trilobites and the ancestral Crustacea ("Protocrustacea" combining Copepodan and Branchiopodan characters) which first gave off the lines of descent of the Entomostraca, and then gave rise to the "Protomalacostraca" from which the

higher Crustacea were derived. Insects and "Myriopods" were evolved from "Protomalacostraca" or "Protocrustacea" (more probably the latter) but not from Trilobites, and it may be worth while briefly to summarize the reasons for deriving Insecta and "Myriopods" from a Crustaceoid stem, in this paper, since the figures illustrating most of the features referred to are available in the plates of this and the preceding paper.

It is inconceivable that the ancestors of forms comprising the majority of the living species of the animal world (as Insects do) should utterly disappear without any trace of living representatives, and an analysis of structural features should reveal what group of Arthropods has preserved the "ancestral tradition" of the precursors of Insects, in the same way that an analysis of structural features revealed that Reptiles, for example, preserved the "ancestral tradition" of the precursors of birds, etc., in other portions of the zoological family tree.

A more comprehensive study of the heads of primitive Insects and their near relatives reveals that the fundamental composition of a primitive Insect's head capsule involves the division of the head capsule into an archicephalic and opisthocephalic region, *arc* and *opc*, by an archicephalic suture *acs*, extending upward from the base of the mandible *md*, and a well-developed downward projecting clypeal region *c* and labrum *l* (particularly the well-developed labrum) characteristic of the primitive insects shown in Figs. 15 and 8 of the previous paper. The Crustacea (Figs. 27, 50, 52 and 57) are the only group which preserves this fundamental arrangement in the truly characteristic fashion and in all its "pristine glory," thus clearly demonstrating that the original condition arose with them, and not with any other group.

Similarly, the hypopharynx and paragnaths, which such primitive Insects as *Machilis* (and other Apterygota) have so slavishly copied from Crustacean models, scrupulously preserving every detail of development (from the embryonic mandibular neuromere), form and function, were derived from Crustacean prototypes alone, since only the Crustacea, among the forms more primitive than Insects, have these structures typically and characteristically developed. (see discussion by Crampton, 1921a).

Insectan embryology clearly indicates that the ancestors of Insects had two pairs of antennae. Here again the Crustacea alone have preserved the "ancestral tradition" since they alone of the forms approaching Insects in their structural modifications exhibit typically and characteristically two pairs of antennae.

The mandible of such primitive Insects as *Machilis*, with its single articulation, in the dorsal region (i.e. without the well developed second point of articulation later developed in insects higher than the Apterygota), with its exaggeratedly long incisor region, and elongated mola (see discussion by Crampton, 1922b) giving it far more of a "Crustacean appearance" than that of a higher insect (even in the nature of its muscles and other internal features), was clearly and unmistakably derived from a Crustacean prototype, since it repeats in every detail the type of mandible found only in Crustacea. "Myriopods" also exhibit traces of tendencies to approach the primitive Insectan type of hugely developed mandible extending backward behind the region of the compound eyes (Figs. 22 and 26) as in *Lepisma* (Fig. 15) for example, but both Insects and "Myrio-

pods" evidently inherited this tendency from a common Crustaceoid source (resembling the condition exhibited by the Crustacean shown in Fig. 29), and only the Crustacea furnish the models from which such a Crustaceoid mandible as that of the primitive Insect *Machilis* could be "copied."

The fringe at the distal end of the endites of Crustacean maxillae etc.—including as it does the apical teeth, a movable midappendix, and (lower down) the modified spines which often have serrated margins (see Crampton, 1923 and 1922a)—is so like the fringe at the distal end of the endite (lacinia) of an Insect-an maxilla, that it is incredible that tendencies to develop structures so strikingly similar in the minutest details could have arisen independently in the two groups; and we are forced to conclude that Insects and Crustacea tend to exhibit such structures because they both inherited this tendency from a common ancestry.

The compound eyes of Insects and Crustacea are so marvellously alike, even in their minutest histological details, that we are forced to conclude that they must have been inherited from a common ancestry; and judging from the other features cited above, that common ancestry must have been Crustaceoid because the Crustacea have "preserved the ancestral tradition" more nearly than any of the groups of higher Arthropods (Insects, "Myriopods" and Crustacea) bound together by similar structural modifications. Not only are the compound eyes of Crustacea such as those shown in Figs. 34, 31, etc., like those of the primitive insect *Machilis* (Fig. 8), but the nature of the elements of the eyes of the Crustacean shown in Fig. 29 is quite suggestive of that of the Insect shown in Fig. 15, and even the four separated ocelli-like elements of the "eye" of the Crustacean shown in Fig. 44 are like the four elements of the "eye" of the Chilopod shown in Fig. 17 in appearance and in being located near the base of the antennae. It is thus very clear that the Crustacea exhibit tendencies later re-appearing in the lines of descent of the Insecta and "Myriopoda," and furnish us the primitive group preserving more nearly than any other the "ancestral tradition," when we attempt to trace the various structural features of Insects and Myriopods back to their origin in forms more primitive than they.

Some "Myriopods" preserve the epicranial suture *ecs* of Fig. 24, or the antennifer *af* of Fig. 26 which are Insectan features (compare *ecs* and *af* of Figs. 7 and 8) and the Insect shown in Fig. 12 retains the postantennal organ *ps* which is a "Myriopod" feature, but it is extremely probable that both Insects and "Myriopods" inherited the tendency to develop such features from some common Crustaceoid ancestry.

"Myriopods," like the higher Crustacea, exhibit a tendency for the segment bearing the "poison-claw," or appendage homologous with the first maxilliped, to become more closely associated with the head, than with the rest of the trunk; and the appendage in question is directed forward exhibiting a marked tendency toward cephalization in both Crustacea and "Myriopods," while the homologue of this appendage in insects, namely the prothoracic leg, shows no tendency toward cephalization, unless the forward-directed prothoracic legs of Protura (in which the anterior legs lie rather closely applied to the head) exhibit a slight trace of such a tendency. The number of appendages entering into the head-complex, however, is so variable even within such homogeneous groups

as the Crustacea and Arachnoids, that such a feature has no phylogenetic significance for denying a common ancestry to forms exhibiting variations in the number of segments exhibiting cephalization; consequently, it is no argument against the common ancestry of Insects "Myriopods" and Crustacea to state that the number of segments entering into the head complex, or exhibiting tendencies to cephalization, differs in the three groups, because this feature is extremely variable even within the group itself (e.g. within the group Crustacea; Arachnoidea etc.). The lower Crustacea have a tendency to restrict the head appendages to the first and second antennae, the mandibles, and the first and second maxillae, as is the case in Insect embryos, and this merely means that Insects were doubtless descended from a very *primitive* Crustaceoid form. This is further indicated by the fact that the endopodite forming the palpus of the first maxillae is large and well developed in Insects, but is greatly reduced in "Myriopods" and Crustacea, indicating that the prototype of such a first maxillary appendage is to be sought in some "Protocrustacean" form.* Such prototypes, however, were evidently more Crustacean than Trilobitan, since the head and its appendages in Trilobites exhibit no structural modifications closely approaching those of Insects, as Crustacea do, and these features merely indicate that insects were descended from a very primitive Crustaceoid type, probably from the Protocrustacea. These points, however, will be more fully discussed elsewhere, and need not be further considered at this time.

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*—That even the Copepoda may exhibit this tendency is indicated in the footnote on page 2.

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ABBREVIATIONS

acs.. Archicephalic suture. *af*.. Antennifer. *ant*.. First and second antennae. *arc*.. Archicephalon. *c*.. Clypeus. *d*.. Frontal doubleure. *e*.. Compound eyes, lateral eyes, and groups of visual elements. *ecs*.. Epicranial suture. *en*.. Endopodite. *ex*.. Exopodite. *f*.. Frontal region. *fs*.. Frontal filament. *gb*.. Gnathobase or endite. *h*.. Hypopharynx (metastome). *l*.. Labrum or prostomium. *li*.. second maxillary or labial appendages. *md*.. mandibular appendages. *mdp*.. Mandibular palpus. *mx*.. first maxillae. *mp*.. Maxilliped (first). *oc*.. Ocelli, median ocelliform structures, etc. *opc*.. Opisthocephalon or gnathocephalon. *pg*.. Paragnatha. *r*.. Rostrum, or rostral plate.

EXPLANATION OF PLATES

Unless otherwise stated, all figures are of the head region. In lateral views, the anterior region of the head is directed toward the right hand margin, in dorsal views, the anterior region is directed toward the top of the page.

- Fig. 55.. *Estheria californica* (Crustacea, Branchiopoda, Conchostraca) lateral view.
- Fig. 56.. *Nebalia bipes* (Crustacea, Phyllocarida, Nebaliacea) lateral view.
- Fig. 57.. *Centropages typicus* (Crustacea, Copepoda, Eucopopoda) lateral view.
- Fig. 58.. *Ar. ulus* sp. (Crustacea, Copepoda, Branchiura) two-thirds dorsal.
- Fig. 59.. A female of *Cypris* not quite sexually mature (Crustacea, Ostracoda, Podocapa) lateral view, after Claus.
- Fig. 60.. *Lepidurus* sp. (Crustacea, Branchiopoda, Notostraca) lateral view.
- Fig. 61.. *Eurycerus lamellatus* (Crustacea, Branchiopoda, Cladocera) lateral view after Weismann.
- Fig. 62.. *Diastylis rathkii* (Crustacea, Peracarida, Cumacea) lateral view.
- Fig. 63.. Larval *Chthamalus stellatus* (Crustacea, Cirripedia, Symmetrica) lateral.
- Fig. 64.. Trilobite, *Triarthrus becki*, lateral view.
- Fig. 65.. Trilobite *Isotelus*, two thirds dorsal.
- Fig. 66.. *Branchiopus* sp. (Crustacea, Branchiopoda, Anostraca), lateral view.
- Fig. 67.. Young *Limulus polyphemus* (Arachnoidea, Merostomata, Xiphysura) two thirds dorsal.
- Fig. 68.. Ordovician Trilobite from Ohio, related to *Calymene*, lateral view.
- Fig. 69.. Annelid *Nereis*, dorsal view, anterior end directed toward bottom of page.
- Fig. 70.. Onychophoran *Peripatus*, lateral view.
- Fig. 71.. Typical Myzostomidan (*Myzostoma cirriferum*) ventral view of anterior region redrawn from Lang and von Graff.
- Fig. 72.. Tardigrade *Echiniscus spinulosus* redrawn from Doyere, lateral view.
- Fig. 73.. Larval Pentastomid or Linguatulid Porocephalus, ventral view, after Stiles.
- Fig. 74.. Annelid *Laodice (Eunice) rubra*, lateral view.
- Fig. 75.. Larval Annelid *Lopadorhynchus*, lateral view, after Kleinberg.
- Fig. 76.. Rotifer, *Pedalion mirum*, lateral view (entire creature) after Hudson.
- Fig. 77.. Female *Artemia* (Crustacea, Branchiopoda, Anostraca) lateral view.
- Fig. 78.. Nereidiformian Polychaete *Tomopteris heligolandis*, two thirds dorsal.
- Fig. 79.. Trilobite (Branchiopod?) *Marella splendens*, dorsal view, anterior and directed downward, after Walcott.
- Fig. 80.. Trilobite *Lichas mephisto*, dorsal view (anterior end downward) after Richter.
- Fig. 81.. Trilobite *Phacops schlotheimi* lateral view.
- Fig. 82.. Ventral view of head of *Triarthrus becki*, redrawn from Raymond.
- Fig. 83.. Frontal view of head of Trilobite *Pliomera fischeri* after Schmitt.
- Fig. 84.. Dorsal view of head of Eurypterid *Eurypterus fischeri* (Merostomata) redrawn from Clarke & Ruedemann.
- Fig. 85.. Merostome *Bunodes lunula*, dorsal view, after Patten.
- Fig. 86.. Trilobite *Triarthrus becki*, dorsal view, after Beecher.
- Fig. 87.. Dorsal view of head of typical scorpion.
- Fig. 88.. Dorsal view of anterior end of head of whip scorpion type of Pedipalpi.
- Fig. 89.. Dorsal view of young Trilobite *Sao hirsuta* after Barande.
- Fig. 90.. Dorsal view of head of young Xiphosuran Merostome, *Limulus polyphemus*.
- Fig. 91.. Dorsal view of head of Pedipali of Tarantula type.
- Fig. 92.. Dorsal view of head of spider of Argiope type.
- Fig. 93.. Dorsal view of typical Solpugid head.

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STUDIES IN THE SCARABAEIDAE (I) (COLEOP.).*

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Aphodius wickhami n. sp.

Length, 5-5.8 mm.; width 2.3-2.6 mm. Moderately elongate; rather strongly convex; slightly wider posteriorly. Black, the legs and sometimes the ventral thoracic sclerites brown; strongly shining throughout.

Head three-fourths as wide as pronotum, strongly convex; three very feeble tuberosities evident on the frontal suture; disk very finely and sparsely punctate, almost impunctate at middle. Clypeus broadly, very feebly emarginate, very broadly rounded on each side of emargination; the sides feebly arcuate. Genae very broadly rounded, less prominent than usual.

Pronotum three-fourths as long as wide, the side margins parallel in basal three-fifths, then feebly converging to apex; base arcuate, feebly sinuate on each side of middle, the marginal line fine and entire; hind angles very obtuse, broadly rounded, but distinct. Disk sparsely punctate, the punctures unequal in size; the larger moderately coarse, almost absent at middle; the smaller fine, scarcely less sparse at middle.

Elytra at base slightly narrower than the pronotum, wider posteriorly. Disk finely striate; the striae with moderately close, fine punctures; intervals flat, without trace of alutaceous sculpture, very finely and sparsely punctate, the punctures more distinct on the sides.

Mesososternum alutaceous, not carinate between the coxae. Metasternum smooth at middle, coarsely punctate and alutaceous on the sides. Abdomen alutaceous, moderately punctate. Anterior tibiae tridentate, the margin feebly crenate above the upper tooth. Middle and hind femora each with a few very fine punctures and with several coarse punctures near apex; middle and posterior tibiae each fimbriate at apex with short, equal spinules; first segment of hind tarsus equal in length to the three following.

Male. Anterior tibial spur stout, acute at apex. Minor spur of middle tibia stout, about one-third as long as the major, obliquely truncate at apex. Metasternum feebly but distinctly depressed at middle.

Female. Anterior tibial spur similar to that of male but slender. Minor

*—Contribution from the Division of Systematic Entomology, Entomological Branch, Dept. of Agric., Ottawa.

spur of middle tibia more than half as long as the major, slender, acute at apex. Metasternum not depressed.

Holotype—♂, Leadville, Col., July 7-14, 1896, 10,000-11,000 ft., (H. F. Wickham), No. 2837 in the Canadian National Collection, Ottawa.

Allotype—♀, same data.

Paratype—♀, Peak Eight, Col., 11,500-12,000 ft., (Wickham).

This species is closely allied to *aleutus*, and the two are probably confused in collections. The form of the head and the lack of microscopic alutaceous sculpture on the elytral intervals distinguish *wickhami*. The head of *wickhami* resembles that of *alternatus* which, however, is less convex and without traces of tubercles.

***Aphodius manitobensis* n. sp.**

Length, 4.4 mm.; width, 2 mm. Oblong, moderately elongate and convex, parallel. Body black throughout, anterior clypeal margin and legs dark brown; strongly shining.

Head three-fourths as wide as the pronotum; moderately convex; rather feebly trituberculate; without clypeal carina; rather coarsely punctured, roughly and closely so near apex, rather sparsely on vertex. Clypeus rather broadly, not deeply emarginate; the angle on each side rounded; the sides feebly arcuate. Genae broadly rounded, moderately prominent.

Pronotum three-fourths as long as wide; the sides feebly arcuate; the hind angles rounded, very obtuse; base arcuate, sinuate on each side of middle, with strong marginal line. Pronotal disk finely and rather sparsely punctate, with a few coarse punctures intermixed, these more numerous on the sides; median line very narrowly impunctate.

Elytra at base slightly narrower than pronotum, scarcely broader posteriorly. Elytral disk finely striate; the striae moderately finely and sparsely punctate; intervals feebly convex, with a faint trace of alutaceous sculpture, the sides feebly crenate by the striae punctures, sparsely and rather finely punctate, the punctures coarser than usual.

Mesosternum alutaceous, the intercoxal process not carinate. Metasternum with a few punctures, the sides alutaceous and rather closely punctate. Abdomen finely punctate. Middle and hind femora finely and very sparsely punctate, each with a short row of coarse punctures near apex. Anterior tibia strongly tridentate, denticulate above the upper tooth. Hind tibia fimbriate with moderately short, equal spinules; first segment of posterior tarsus shorter than the three following.

Male. Median cephalic tubercle somewhat more prominent than the lateral tubercles. Anterior tibial spur stout, at middle rather strongly curved caudad, the apex bluntly pointed. Minor spur of middle tibia less than half as long as the major, the apex truncate.

Holotype—♂, Aweme, Manitoba, June 4, 1927, (N. Criddle); No. 2651 in the Canadian National Collection, Ottawa.

This species is most closely allied to the more robust *uricola* but is very easily distinguished by the roughly punctate clypeus, the strongly punctate elytral intervals, and the male sexual characters. In *uricola*, the clypeus is sparsely punctate and the elytral intervals are very finely punctate. The apical spinules

of the hind tibia of *manitobensis* are longer and more slender than in its allies, but the species cannot be referred to the series in which the spinules are unequal.

***Aphodius haywardi* n. sp.**

Length, 7.5 mm.; width, 3.5 mm. Oblong, moderately convex and elongate, parallel. Head dark reddish brown; blackish at middle; pronotum blackish, the sides broadly dark reddish brown; elytra and legs reddish brown; venter dark reddish brown; surface strongly shining.

Head two-thirds as wide as pronotum; with two very feeble tuberosities on the frontal suture; finely and sparsely punctate throughout. Clypeus broadly and shallowly emarginate, very obtusely angulate on each side, the angles feebly reflexed. Genae broadly rounded, moderately prominent.

Pronotum two-thirds as long as wide; the angles very obtuse; the sides narrowly and rather feebly explanate, scarcely arcuate; base arcuate, with entire marginal line. Pronotal disk without concavities near the hind angles; puncturation intermixed, the smaller punctures very fine and sparse; the larger punctures moderately coarse and sparse, somewhat closer near the lateral margins; a transverse oval area extending from middle almost to apex virtually impunctate. Scutellum finely, rather closely punctate on basal half.

Elytra at base slightly narrower than the pronotum, slightly wider posteriorly. Elytral disk finely and sharply striate, the striae with fine, well-spaced punctures; intervals almost flat, punctulate, the punctules extremely fine and sparse.

Mesosternum alutaceous, the sides punctate, the intercoxal process not carinate. Metasternum finely and sparsely punctate at middle, closely and coarsely so on the sides. Abdomen finely punctate. Ventral face of anterior femur finely punctate, moderately hirsute. Anterior tibia strongly tridentate, the margin more or less serrulate above the upper tooth. Middle femur with a few coarse punctures at middle. Hind femur sparsely, coarsely punctate on posterior third. First segment of posterior tarsus very slightly shorter than the three following.

Male. Anterior tibial spur stout, long, parallel, rather strongly curved; the apex acute. Minor spur of middle tibia about one-third as long as the major, very stout, abruptly incurved at apex. Middle trochanter closely fimbriate with long yellow hairs. Middle and hind femora and hind trochanters each with several scattered hairs.

Holotype—♂, Vicinity of Rico, Dolores Co., Colorado, 85-10,000 ft., July 19-22, 1885, Hayward Coll.; in the Museum of Comparative Zoology.

This species is closely allied to *phaeopterus* to which it traces in the tables. It differs in pronotal sculpture and in some sexual characters. In *phaeopterus*, the pronotum is very distinctly punctate throughout, and in the males the middle and hind femora each bear a conspicuous patch of yellow hairs on the posterior half near the trochanter which is conspicuously fimbriate.

***Aphodius hirsutus* n. sp.**

Length, 5.2-5.4 mm.; width, 2.6 mm. Oblong, moderately elongate and convex, parallel. Reddish-yellow throughout, strongly shining.

Head two-thirds as wide as pronotum; moderately convex; with two transverse, very feebly tuberosities on the frontal suture. Vertex finely, moderately closely punctate in front and at base, a transverse impunctate area at middle;

clypeus finely and sparsely granulate throughout, the granules quite feeble, the anterior margin broadly truncate, a small slender tooth on each side of truncation, the side margins moderately arcuate and closely fimbriate with short yellow hairs. Genae broadly rounded, moderately prominent.

Pronotum seven-tenths as long as wide, the front angles obtuse; the sides moderately arcuate; the hind angles very broadly rounded, not defined; the side and basal margin closely fimbriate; base arcuate, the marginal line deep and entire. Pronotal disk moderately closely and coarsely punctate, the punctures finer and less close at middle; with a few very short, inconspicuous hairs on basal third.

Elytra at base equal in width to the pronotum, slightly wider posteriorly; sides closely fimbriate with moderately long, yellow hairs. Disk finely, not deeply striate; the striate with fine, feeble, well-paced punctures; intervals almost flat, each with an irregular row of shallow punctures on each side; the punctures as coarse as those of the pronotal sides and each with a moderately short, erect, yellow hair.

Mesosternum shining, very feebly alutaceous, the intercoxal process not carinate. Metasternum finely and very sparsely punctate at middle, closely and rather coarsely punctate on the sides. Abdomen with very fine, sparse, indistinct punctures; clothed with sparse, yellow hairs. Ventral face of anterior femur with a row of close hairs. Anterior tibia very strongly tridentate, the margin above the upper tooth entire. Middle and hind femora each with a row of coarse punctures and a few scattered fine punctures. First segment of posterior tarsus equal in length to the two following.

Male. Internal margin of anterior tibia feebly but distinctly sinuate, the inner apical angle rectangular but rather broadly rounded; the tibial spur moderately stout, very short, not quite reaching the tarsus, subequal in length to the first tarsal segment. Spurs of middle tibiae of the usual female type.

Female. Anterior tibia normal, the inner margin not sinuate, the inner apical angle very obtuse and very broadly rounded as usual; the tibial spur slender, acute, and normal, attaining the apex of the second tarsal segment. Spurs of middle tibia as in the male.

Holotype—♂, Yakima R., W. T., Opp. Ellensburg, July 8, 9, '82; in the Museum of Comparative Zoology.

Allotype—♀, same data.

This species is closely allied to *militaris* but is readily distinguished by the conspicuously hirsute elytra and the anterior tibial spur of the male. In *militaris*, the male fore tibiae are without spurs and the elytra are glabrous.

***Aphodius albertanus* n. sp.**

Length, 4.2-5.5 mm.; width 2-2.5 mm. Moderately elongate and convex; slightly wider posteriorly. Head and pronotum black, the clypeal margin and anterior pronotal angles obscurely reddish-brown; elytra and ventral thoracic sclerites dark reddish-brown; abdomen and legs paler reddish brown; body shining throughout.

Head two-thirds as wide as pronotum, moderately convex; three very feeble tuberosities evident on the frontal suture; disk rather finely punctate, sparsely so at base and middle, closely so near anterior margin. Clypeus broadly, feebly

emarginate, very broadly rounded on each side of the emargination; the sides feebly arcuate. Genae very broadly rounded, not prominent.

Pronotum two-thirds as long as wide; the side margins moderately arcuate, subparallel in basal half; base arcuate, feebly sinuate on each side of middle, the marginal line fine and entire; hind angles obtuse, broadly rounded but distinct. Disk finely and sparsely punctate throughout, a few larger punctures intermixed on the sides.

Elytra slightly wider posteriorly. Disk finely striate, the striae with moderately close, fine punctures; intervals feebly convex, very finely and very sparsely punctate.

Mesosternum alutaceous, not carinate between the coxae. Metasternum finely, very sparsely punctate at middle, alutaceous and less finely and sparsely punctate on the sides. Abdomen alutaceous, moderately closely, not coarsely punctate. Anterior tibia tridentate, the margin very feebly or not crenate above the upper tooth. Middle and hind femora each with a few very fine punctures and with several coarse punctures near apex; middle and hind tibiae each fimbriate at apex with unequal spinules; first segment of hind tarsus slightly longer than the two following.

Male. Anterior tibial spur stout and long, extending slightly beyond the apex of the third tarsal segment; moderately and evenly arcuate. Minor spur of middle tibia moderately stout, less than half as long as the major, the apex subtruncate. Prothorax slightly wider than elytra at base.

Female. Anterior tibial spur similar to that of male but much more slender and shorter, extending slightly beyond the apex of the second tarsal segment. Minor spur of middle tibia about half as long as the major, acute at apex. Prothorax smaller, slightly narrower than elytra at base.

Holotype—♂, Banff, Alta., July 21, 1925, (Owen Bryant); No. 2838 in the Canadian National Collection, Ottawa.

Allotype—♀, Banff, Alta., June 15, 1927, (Owen Bryant).

Paratypes—6 ♀, 1 ♀, Banff, Alta.; 2 ♀, Kananaskis, Alta.; 1 ♂, 1 ♀, Calgary, Alta., 2 ♂, 1 ♀, Northwest Territories.

This species has been labeled *congregatus* in collections. It is closely allied to *cruentatus*, but is distinct by its smaller size, less distinctly punctate elytral intervals, and male sexual characters. The examples labeled Northwest Territories were collected long ago and probably came from a locality which is now included in Alberta or Saskatchewan.

***Aphodius fimbripes* n. sp.**

Length, 6.4-6.8 mm.; width, 3 mm. Elongate, parallel, subdepressed, shining throughout. Head and pronotum very dark reddish brown or blackish, the lateral and apical margins obscurely paler; elytra reddish brown; underside and legs reddish brown, paler than the elytra.

Head two-thirds as wide as pronotum, feebly convex; frontal suture distinct, elevated to form three very feeble tubercles; head finely and sparsely punctate, the clypeus indistinctly so at middle, the vertex impunctate. Clypeus very broadly and very shallowly emarginate; the angle on each side very broadly rounded; the sides scarcely arcuate and conspicuously fimbriate with moderately long,

dense, brownish-yellow hairs. Genae obtuse, moderately prominent, fimbriate, the hairs similar to those of the clypeus but longer.

Pronotum feebly convex; almost three-fourths as long as wide; the sides feebly arcuate and conspicuously fimbriate; the hairs near the anterior angles similar to those of the genae, shorter posteriorly; base arcuate, distinctly sinuate on each side of middle and oblique near the hind angles which are very obtuse; basal marginal line strong. Pronotal disk finely and sparsely punctate, the punctures slightly unequal, less sparse and less fine on the sides.

Elytra at base slightly narrower than the pronotum, scarcely wider posteriorly, the external margins fimbriate except at apex with moderately long, brownish-yellow hairs. Elytral disk rather coarsely striate, the striae with moderate, well-spaced punctures; intervals feebly convex, microscopically alutaceous, each with two rows of fine punctures, these somewhat irregular and near the striae; ninth interval more strongly convex, especially near the humerus.

Mesosternum not carinate between the coxae. Metasternum coarsely and sparsely punctured on each side, a row of close punctures on each side of a median flattened area, all punctures bearing hairs. All femora fimbriate on the anterior margins with long, brownish-yellow hairs; the middle and posterior femora impunctate except for a row of hair bearing punctures near apex; anterior tibiae conspicuously fimbriate internally with similar hairs, strongly tridentate externally and strongly denticulate above the upper tooth; middle and hind tibiae with sparse, long hairs internally, each fimbriate at apex with long, coarse, subequal spinules; first segment of hind tarsus subequal in length to the three following.

Male. Anterior tibial spur feebly incurved at apex, short and stout, acutely pointed. Minor spur of middle tibia stout, less than half as long as the major; at apex squarely truncate, each angle slightly produced laterally.

Female. Anterior tibial spur not incurved at apex, slightly less stout. Minor spur of middle tibia half as long as the major, slender, the apex pointed.

Holotype—♂, Milford, Utah, 4900 ft., May 14-20, 1919 (W. Knaus); No. 2830 in the Canadian National Collection, Ottawa.

Allotype—♀, Milford, Utah, July 7 (Wickham); in the Museum of Comparative Zoology.

Paratypes—1 ♂, same data as holotype; 3 ♀, same data as allotype; 1 ♂, Nevada.

This species is closely allied to *cruentatus* but differs by its less robust, more parallel form and by its conspicuously fimbriate margins and legs. In *cruentatus*, there are no hairs on the elytral margin except a few at the humeri; in *fimbripes*, these margins are conspicuously fimbriate.

***Aphodius peculiosus awemeanus* n. subsp.**

In this northern form, the size is larger and the pronotum is slightly wider than in typical *peculiosus*. In a small series of typical *peculiosus* from Anadarko, Oklahoma, the length varies from 3.1 to 3.5 mm. and the pronotum is slightly less than two-thirds as long as wide. In *awemeanus* the length varies from 3.8 to 5 mm., and the pronotum is seven-tenths as long as wide. The secondary sexual characters of *awemeanus* are of the usual type. In the male, the anterior tibial spur is slightly stouter, and the minor spur of the middle tibia is less than half as long as the major, obliquely truncate and bluntly pointed at the apex. In the

female, the minor spur of the middle tibia is slightly more than half as long as the major, more slender, and acute at apex.

Holotype—♂, Aweme, Manitoba, November 6, 1910, (N. Criddle); No. 2831 in the Canadian National Collection, Ottawa.

Allotype—♀, same data as holotype.

Paratypes—33, same data, on various dates; 1, Stony Mountain, Manitoba, November 1, 1911, (J. B. Wallis).

***Ataenius schwarzi* (Linell).**

Psammodius schwarzi Linell must be placed in the genus *Ataenius*. Mr. L. B. Buchanan has examined the type and has found that the species agrees with *Ataenius* in all essential respects, especially in respect to the characters of the hind tibiae. Study of the mouth parts of specimens in the Canadian National Collection show that the maxillae are of the membranous type found in *Ataenius*.

In Horn's table to the species of *Ataenius* (Trans. Am. Ent. Soc., XIV, 68), *schwarzi* traces to the *cognatus-californicus* couplet. The verrucose clypeus and stouter legs of *schwarzi* readily separate it from these species; these characters probably caused Linell to associate the species with *Psammodius*.

(To be Continued)

BOOK REVIEW

Leaf-mining Insects. James G. Needham, Stuart W. Frost and Beatrice H. Tothill. vi-351 pp., 91 illustrations. Baltimore, The William and Wilkins Company—1928.

This work is essentially a compilation of data from the existing literature on leaf-mining insects. It contains very little new information but serves a useful purpose by bringing together the widely scattered papers on the subject. The text is very readable. The main points of interest concerning every type of leaf-mine and leaf-miner are discussed in lucid untechnical language which cannot fail to appeal to the general reader. As a reference work, the book is of considerable value to the student and fills a long-felt need. The first two chapters are of a general character and touch upon the various biological, ecological and morphological phases of the leaf-mining habit. The remainder of the text treats of leaf-miners of the different orders. Nine chapters are devoted to the Lepidoptera and one each to Coleoptera, Hymenoptera and Diptera. The last part of the book consists of species and host plant lists with cross-references and a bibliography.

In the Lepidoptera, the suborder Jugatae is represented by the Eriocraniidae. The life-history and habits of *Eriocrania (Mnemonica) auricyanea* Wlsh. are discussed at length and two European species are mentioned. The leaf-mining Frenatae are treated under the following headings: Incurvarioidea, Nepticuloidea, Tineoidea, Cynodioidea, Gelechioidea, Yponomeutoidea, Tortricioidea, Pyraloidea and Noctuoidea. A detailed account of the treatment of each of the seventeen families would require too much space. Suffice it to say that generally one or two typical insects in each group are discussed more or less thoroughly, the allied species being mentioned in connection with some of the features peculiar to them. At first sight, it might appear that some of the smaller groups, e.g. the Incurvaridae have received a disproportionate amount of attention as compared with larger

groups such as the Lithocolletinae. This, however, is somewhat compensated by numerous allusions in other parts of the text to members of the larger groups. A few minor inaccuracies, especially in details of life-histories and habits, may be expected to creep into an uncritical account based upon the work of many authors. Whilst it is probably unreasonable to expect that the compiler check up on all the observations of the workers to whom he refers, the recording of erroneous statements in a work such as the present treatise has a regrettable tendency to perpetuate the errors in the mind of the readers. This is particularly true in the case of insects which are rather prominently featured.

The leaf-miners of three Coleopterous, two Hymenopterous and nine Dipterous families form the subject matter of Chapters XII to XIV. The chapter on Diptera contains some very useful keys based both on the types of mine and on the larval characters.

To the working entomologist the last part of the book, namely the species and food plant lists and the bibliography, is undoubtedly the most valuable contribution. Most of the known species of leaf-miners appear in the lists, but several gracilariids are not included and the absence from the Tortricioidea of such a common species as *Taniva albolineana* Kearf. and of *Recurvaria gibsonella* Kearf. from the Gelechioidea constitutes a quite noticeable omission.

The bibliography, in the words of the authors, covers "only the outstanding papers;" a more complete list of references would not have detracted from the excellence of the work. A paper, such as Snodgrass' article on *Coptodisca splendoriferella* and *Bucculatrix pomifoliella*, to mention only one, should certainly be considered of sufficient importance to be mentioned.

J. J. de Gryse.

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